U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

6.2.1.2 SUBCOMPARTMENT ANALYSIS

REVIEW RESPONSIBILITIES

Primary - Containment Systems Branch (CSB)

Secondary - None

I. AREAS OF REVIEW

The CSB reviews the information presented by the applicant in the safety analysis report concerning the determination of the design differential pressure values for containment subcompartments. A subcompartment is defined as any fully or partially enclosed volume within the primary containment that houses high energy piping and would limit the flow of fluid to the main containment volume in the event of a postulated pipe rupture within the volume. A short-term pressure pulse would exist inside a containment subcompartment following a pipe rupture within the volume. This pressure transient produces a pressure differential across the walls of the subcompartment which reaches a maximum value generally within the first second after blowdown begins. The magnitude of the peak value is a function of several parameters, which include blowdown mass and energy release rates, subcompartment volume, vent area, and vent flow behavior. A transient differential pressure response analysis should be provided for each subcompartment or group of subcompartments that meets the above definition.

The CSB review includes the distribution of the mass and energy released into the break compartment, nodalization of subcompartments, subcompartment vent flow behavior, and subcompartment design pressure margins.

The CSB review of the subcompartment model includes the basis for the nodalization within each subcompartment, the initial thermodynamic conditions within each subcompartment, the nature of each vent flow path considered, and the extent of entrainment assumed in the vent flow mixture. The review may also include an analysis of the dynamic characteristics of components, such as doors, blowout panels, or sand plugs, that must open or be removed to provide a vent flow path, and the methods and results of components tests performed to demonstrate the validity of these analyses. The analytical procedure to determine the loss

coefficients and inertia terms (L/A, ft^{-1}) for each vent flow path, and to predict the vent mass flow rates, is reviewed. The design pressure chosen for each subcompartment is also reviewed.

The CSB will coordinate other branch evaluations that interface with the overall review of the containment subcompartments. The Mechanical Engineering Branch (MEB) and the Structural Engineering Branch (SEB), as part of their primary review responsibility for SRP Sections 3.6.2 and 3.8.3, respectively, will review the mechanical and structural design of movable and stationary devices provided for vent flow control in containment subcompartments.

For those areas of review identified above as being reviewed as part of the primary review responsibility of other branches, the acceptance criteria and their methods of applications are contained in the SRP sections identified as the primary review responsibility of those branches.

II. ACCEPTANCE CRITERIA

The acceptance criteria given below apply to the design and functional capability of subcompartments in the primary containment. CSB accepts the containment design of subcompartments if the relevant requirements of General Design Criteria 4 and 50 are complied with. The relevant requirements are as follows:

A. General Design Criterion 4, as it relates to the environmental and missile protection provided to assure that structures, systems and components important to safety be designed to accommodate the dynamic effects (e.g., effects of missiles, pipe whipping, and discharging fluids that may result from equipment failures) that may occur during plant normal operations or during an accident.

B. General Design Criterion 50, as it relates to the subcompartments being designed with sufficient margin to prevent fracture of the structure due to pressure differential across the walls of the subcompartment. In meeting the requirements of GDC 50, the following specific criterion or criteria that pertain to the design and functional capability of containment subcompartments are used as indicated below:

   1. The initial atmospheric conditions within a subcompartment should be selected to maximize the resultant differential pressure. An acceptable model would be to assume air at the maximum allowable temperature, minimum absolute pressure, and zero percent relative humidity. If the assumed initial atmospheric conditions differ from these, the selected values should be justified.

      Another model that is also acceptable, for a restricted class of subcompartments, involves simplifying the air model outlined above. For this model, the initial atmosphere within the subcompartment is modeled as a homogeneous water-steam mixture with an average density equivalent to the dry air model. This approach should be limited to subcompartments that have choked flow within the vents. However, the adequacy of this simplified model for subcompartments having primarily subsonic flow through the vents has not been established.

2. Subcompartment nodalization schemes should be chosen such that there is no substantial pressure gradient within a node, i.e., the nodalization scheme should be verified by a sensitivity study that includes increasing the number of nodes until the peak calculated pressures converge to small resultant changes. The guideline of Section 3.2 of NUREG-0609 should be followed and a nodalization sensitivity study should be performed which includes consideration of spatial pressure variation, e.g., pressure variations circumferentially, axially and radially within the subcompartment, for use in calculating the transient forces and moments acting on components.

3. If vent flow paths are used which are not immediately available at the time of pipe rupture, the following criteria apply:

   a. The vent area and resistance as a function of time after the break should be based on a dynamic analysis of the subcompartment pressure response to pipe ruptures.

   b. The validity of the analysis should be supported by experimental data or a testing program should be proposed at the construction permit stage that will support this analysis.

   c. In meeting the requirements of GDC 4, the effects of missiles that may be generated during the transient should be considered in the safety analysis.

4. The vent flow behavior through all flow paths within the nodalized compartment model should be based on a homogeneous mixture in thermal equilibrium, with the assumption of 100% water entrainment. In addition, the selected vent critical flow correlation should be conservative with respect to available experimental data. Currently acceptable vent critical flow correlations are the "frictionless Moody" (Ref. 16) with a multiplier of 0.6 for water-steam mixtures, and the thermal homogeneous equilibrium model for air-steam-water mixtures.

5. At the construction permit stage, a factor of 1.4 should be applied to the peak differential pressure calculated in a manner found acceptable to the CSB for the subcompartment, structure and the enclosed components, for use in the design of the structure and the component supports. At the operating license stage, the peak calculated differential pressure should not exceed the design pressure. It is expected that the peak calculated differential pressure will not be substantially different from that of the construction permit stage. However, improvements in the analytical models or changes in the as-built subcompartment may affect the available margin.

III. REVIEW PROCEDURES

The procedures described below are followed for the subcompartment analysis review. The reviewer selects and emphasizes material from these procedures as may be appropriate for a particular case. Portions of the review may be carried out on a generic basis or by adopting the results of previous reviews of plants with essentially the same subcompartment and high pressure piping design.

Upon request from the primary reviewer, the other review branches will provide input for the areas of review stated in subsection I of this SRP section. The primary reviewer obtains and uses such input as required to assure that this review procedure is complete.

The CSB may perform confirmatory analyses of the blowdown mass and energy profiles within a subcompartment. The analysis is done using the RELAP-4 computer program (Reference 15) or the COMPARE computer program (Reference 14). The purpose of the analysis is to confirm the predictions of the mass and energy release rates appearing in the safety analysis report, and to confirm that an appropriate break location has been considered in this analysis.

The CSB determines the adequacy of the information in the safety analysis report regarding subcompartment volumes, vent areas, vent resistances, and inertia terms. If a subcompartment must rely on doors, blowout panels, or equivalent devices to increase vent areas, or unique flow limiting devices to control vent flows, the CSB reviews the analysis and testing programs that substantiate their use. The MEB and SEB will evaluate the mechanical and structural design of such flow control devices as part of their review responsibility under SRP Sections 3.6.2 and 3.8.3.

The CSB reviews the nodalization of each subcompartment to determine the adequacy of the calculational model. As necessary, CSB performs iterative nodalization studies for subcompartments to confirm that sufficient nodes have been included in the model.

The CSB compares the initial subcompartment air pressure, temperature, and humidity conditions to the criteria given in subsection II, above, to assure that conservative conditions were selected.

The CSB reviews the bases, correlations, and computer codes used to predict subsonic and sonic vent flow behavior and the capability of the code to model compressible and incompressible flow. The bases should include comparisons of the correlations to both experimental data and recognized alternate correlations that have been accepted by the staff.

Using the nodalization of each subcompartment as specified in the safety analysis report, the CSB performs analyses using one of several available computer programs to determine the adequacy of the calculated peak differential pressure. The computer program used will depend upon the subcompartment under review as well as the flow regime. At the present time, the two programs used by the CSB are RELAP-4 (Ref. 15) and COMPARE (Ref. 14).

At the construction permit stage, the CSB will ascertain that the subcompartment design procedures include appropriate margins above the calculated values, as given in subsection II, above.

IV. EVALUATION FINDINGS

The conclusions reached on completion of the review of this SRP section are presented in SRP Section 6.2.1.

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

VI. REFERENCES

The references for this SRP section are those listed in SRP Section 6.2.1.